axes so that an absolute value of a control error in the direction of the third axis is minimized.

36. A probe scanning microscope according to claim 35; wherein the sampling pulse generating means generates a sampling pulse every time the probe position in the direction of the axis having the higher scanning frequency becomes a predetermined value.

ADDITIONAL FEE:

A check in the amount of $288.00 is enclosed to cover the cost of 16 claims in excess of 20 total. Should the check prove insufficient for any reason, authorization is hereby given to charge any such deficiency to our Deposit Account No. 01-0268.

REMARKS

In the last Office Action, claims 1-17 were rejected under 35 U.S.C. §103(a) as being unpatentable by U.S. Patent No. 5,204,531 to Elings ("Elings") in view of U.S. Patent No. 6,189,374 to Adderton ("Adderton").

By the present response, the specification has been suitably revised in minor editorial respects to improve the wording and correct informalities. Claims 1-17 have been amended in formal respects to improve the wording and place

them in better conformance with U.S. practice. In addition, claim 1 has been amended to clarify the nature of the invention by reciting that the displacement detection means measures relative displacement of the probe by measuring displacement of the scanning means. To obtain a fuller and more comprehensive scope of coverage, new claims 18-36 have been added. Adequate support for the subject matter recited in the newly added claims may be found in the specification as originally filed.

Applicants respectfully submit that claims 1-36 patentably distinguish over the prior art of record.

Amended independent claim 1 recites a scanning probe microscope comprising a probe, means for maintaining the probe in close proximity to the sample surface, scanning means for raster scanning the probe along first and second orthogonal scanning axes substantially parallel to the sample surface and maintaining the probe in close proximity to the sample to cause the probe to move relatively in the direction of a third scanning axis orthogonal to the first and second axes to follow undulations on the sample surface, scanning control means for controlling relative raster scanning of the probe with respect to the sample, and displacement detection means for measuring relative position and displacement of the probe by measuring displacement of the scanning means in the

direction of the second scanning axis or the third scanning axis relative to the sample and outputting a feedback signal based on the detected position and displacement, the feedback signal being used for controlling the probe position.

As described at pages 1-2 of the specification, in a conventional scanning probe microscope (SPM), a sample is mounted to a sample stage above an XYZ translator and brought into contact with a sharpened probe fixed to the tip of a cantilever, and the sample is scanned in the XY plane by the XYZ translator. During scanning, deflection of the cantilever is monitored by a deflection detector. A controller performs feedback control so that cantilever deflection is fixed, and the position of the sample in the Z direction is adjusted by the XYZ translator.

More specifically, in the conventional SPM the sample is raster scanned relative to the probe using the XYZ translator in a high frequency axis (X axis) and a low frequency axis (Y axis) while probe deflection is measured in the third axis (Z axis) to follow undulations on the sample surface. However, the scanning is distorted due to hysteresis in the XYZ translator, which is generally formed using a piezoelectric actuator. Conventional means used to combat this problem include measuring hysteresis values prior to conducting sample measurements and using the measured values

as compensation values to ensure that the amount of displacement of the XYZ translator becomes linear with respect to time.

Methods currently being considered to overcome the foregoing problem entail measuring the amount of displacement of the XYZ translator using a displacement sensor and using the detected displacement to generate an image or to perform feedback control of the probe position during scanning.

However, the above-described methods either fail to account for deterioration of component parts over time, or require an inordinate amount of data processing.

The present invention overcomes the foregoing problems and provides a scanning probe microscope which is not subject to the influence of hysteresis of a piezoelectric element or deterioration with age, which reduces the amount of data processing required, and which is capable of increasing scanning frequency band limits.

In accordance with the present invention, a scanning probe microscope is provided with scanning control means for controlling raster scanning of an XYZ translator and displacement detection means for detecting the amount of displacement of the XYZ translator and outputting a feedback signal based on the detected displacement for controlling the probe position.

In the embodiment illustrated in Fig. 2 of the application drawings, for instance, variations with time of the amount of relative displacement of the probe in the direction of the higher frequency scanning axis 201 and in the direction of the lower frequency scanning axis 202 are shown. The amount of displacement of the probe in the direction of the lower frequency scanning axis is maintained constant by feedback control during one period of the high frequency scanning axis, and is increased by a fixed amount after each such period. As a result, it is possible to remove the effects of creep and drift in the direction of the lower frequency scanning axis, and the data required to generate an image is made up of relative displacement of the probe in the direction of the higher frequency scanning axis and relative displacement of the probe in the direction of the third axis, which are obtained through interpolation of data for the high frequency scanning axis, making it possible to reduce the amount of data and computation time. Thus it is possible to carry out high speed scanning by performing feedback control only in the direction of the low frequency scanning axis.

Independent claim 1 recites that the displacement detection means measures the relative position and displacement of the probe relative to the sample <u>by measuring displacement of the scanning means in the direction of the</u>

second scanning axis or the third scanning axis and outputs a feedback signal based on the detected position and displacement, the feedback signal being used for controlling the probe position.

No corresponding structure is disclosed or suggested by the prior art of record.

Elings discloses an SPM having a tubular piezoelectric actuator that performs three-axis raster scanning under feedback control to form a topographic image of a sample surface, the scanning being performed faster in a first axis than in a second axis. Adderton discloses the use of two feedback loops including a first loop for controlling a cantilever to maintain a constant force between the cantilever and the sample and a second loop for controlling a Z actuator at a lower speed than the first feedback loop. A deflection detector 30 measures cantilever deflection to enable an image to be formed.

However, neither Elings nor Adderton discloses or suggests displacement detection means for measuring probe position by measuring displacement of scanning means in the direction of a second scanning axis or third scanning axis as recited in claim 1.

As pointed out above, the displacement detector of the present invention detects displacement of the scanning means on one axis in order to produce a feedback signal used

to maintain the probe scanning constant in that axis while scanning in another axis. In the preferred embodiment described above, the displacement detector detects displacement of an XYZ translator in the slower of the X-Y scanning axes.

Although Adderton discloses a deflection detector for detecting cantilever deflections in the Z-direction, the reference does not disclose a displacement detector for detecting displacement of a scanning means in one axis as required by amended independent claim 1.

Newly added independent claim 25 contains similar subject matter and is allowable for the same reasons discussed above.

The dependent claims also contain subject matter that patentably distinguishes over the prior art of record. Dependent claim 4 recites that the scanning control means controls the probe position in the direction of the scanning axis having the lower scanning frequency such that it becomes constant during either an entire period or a portion of a period of scanning in the direction of the other scanning axis having the higher scanning frequency. Dependent claim 5 contains similar subject matter. Dependent claim 6 recites that a scanning range of the sample surface in a direction of at least one of the first scanning axis and the second

scanning axis is larger than and includes a range of the sample surface being observed. Dependent claim 7 contains similar subject matter. Dependent claim 8 recites that the displacement detection means commences sampling and storage of relative position and displacement values of the probe when the probe position in a direction of the higher frequency scanning axis enters a range being observed. Dependent claim 9 recites that sampling and storage of relative position or displacement values of the probe is commenced when the rate of change over time of the relative position or displacement of the probe in the direction of the higher frequency scanning axis becomes constant or becomes a predetermined value. Dependent claim 10 contains the combined subject matter of claims 8 and 9. Dependent claim 11 recites that a rate of change over time of the relative position and displacement of the probe in the direction of the higher frequency scanning axis become a set value until the relative probe position in the direction of the higher frequency scanning axis enters a range being observed. Dependent claim 12 recites that the probe displacement in the direction of the higher frequency scanning axis is larger than a region to be observed so that rate of change over time of the relative position and displacement of the probe with respect to the sample in the direction of the higher frequency scanning axis become

constant until the relative position and displacement of the probe with respect to the sample in the direction of the scanning axis having the higher scanning frequency enter a range being observed. Dependent claims 13-16 recite that the scanning control means comprises scanning speed adjustment means for adjusting the speed of the raster scanning in the direction of one of the first and second scanning axes, and sampling pulse generating means for generating sampling pulses at predetermined times. The combined teachings of Elings and Adderton fail to disclose or suggest any of the foregoing subject matter. Newly added dependent claims 26-36 contain similar subject matter to that recited in the original dependent claims and are patentably distinct from the references for the same reasons.

Accordingly, applicants respectfully submit that claims 1-36 patentably distinguish over the prior art of record and that the claim rejections under 35 U.S.C. §103(a) should be withdrawn.

In view of the foregoing amendments and discussion, the application is now believed to be in allowable form.

Accordingly, favorable reconsideration and allowance of the claims are most respectfully requested.

Respectfully submitted,

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MAILING CERTIFICATE

I hereby certify that this correspondence is being deposited with the United States Postal Service as first-class mail in an envelope addressed to: COMMISSIONER OF PATENTS & TRADEMARKS, Washington, D.C. 20231, on the date indicated below.

Bruce L. Adams
Name

____
Signature

April 10, 2003
Date

VERSION WITH MARKINGS TO SHOW CHANGES MADE

IN THE SPECIFICATION:

Paragraph beginning at line 4 of page 1 has been revised as follows:

Fig. 10 is an outline view of an atomic force microscope (AFM), which is [being] one type of scanning probe microscope (SPM) [,] of the related art. In Fig. 10, reference numeral 1001 is an XYZ translator, 1002 is a sample stage, 1003 is a sample, 1004 is a cantilever, 1005 is a cantilever deflection detector, 1006 is a controller, and 1007 is a computer.

Paragraph beginning at line 8 of page 1 has been revised as follows:

In [With] this related art AFM, the sample 1003 is mounted on the sample stage 1002 above the XYZ translator 1001, the sample 1003 is brought into contact with a sharpened probe fixed to the tip of the cantilever 1004, and the sample is scanned in the X-Y plane by the XYZ translator 1001. During [At] this time, deflection of the cantilever is monitored by the deflection detector 1005, the controller 1006 performs feedback control so that deflection is fixed, and the position of the sample 1003 in the Z direction is adjusted by

the XYZ translator 1001. Microscopic structures on the sample surface can be observed by mapping adjustment amounts for each position on the surface of the sample onto a screen using a computer.

IN THE CLAIMS:

Claims 1-17 have been amended as follows:

1. (Amended) A [In a] scanning probe microscope which observes microscopic structures on a sample surface, comprising: a probe responsive to an atomic force generated when brought into close proximity to the sample surface; scanning means for [by, at the same time as] performing raster scanning of the probe along a first scanning axis substantially parallel to the sample surface and a second scanning axis substantially parallel to the sample surface and orthogonal to the first scanning axis of the [a] sample surface [using a microscopic probe,] and maintaining the probe in close proximity to the sample surface to cause [causing] the probe to move relatively in the direction of a third scanning axis orthogonal to both the first scanning axis and the second scanning axis so as to follow undulations on the sample surface; [, the improvement comprising:] scanning control means for controlling relative raster scanning of the probe with respect to the sample; [,] and displacement

detection means for measuring relative position and displacement of the probe relative to the sample by measuring displacement of the scanning means in the direction of the second scanning axis or the third scanning axis [relative to the sample] and outputting a feedback signal based on the detected position and displacement, the feedback signal being used for controlling the probe position.

2. (Amended) A [The] scanning probe microscope according to [of] claim 1; [,] wherein the displacement detection means simultaneously detects relative position or displacement of the probe with respect to the sample in the direction of the first scanning axis, the second scanning axis and the third scanning axis; and further comprising a storage device for storing detection [, and saves] results of the displacement detection means; and a computer for generating [in a storage device, and] an observation image of the sample surface [is generated] based on the relative position or displacement of the probe [sample] with respect to the sample for each of the scanning axes saved in the storage device.

3. (Amended) A [The] scanning probe microscope according to [of] claim 2; [,] wherein the scanning control means receives the feedback signal and performs feedback control in the direction of at least one [axis,] of the first scanning axis and the second scanning axis of the raster

scanning [,] based on relative position or displacement of the probe with respect to the sample detected by the displacement detection means.

4. (Amended) A [The] scanning probe microscope according to [of] claim 3; [,] wherein the scanning control means receives the feedback signal and performs feedback control by controlling the probe position in accordance therewith such [so] that the relative position or displacement of the probe with respect to the sample in the direction of the [a] scanning axis having the lower [having a low] scanning frequency [,] of the first scanning axis and the second scanning axis [,] becomes constant during either an entire [one] period or a portion of a period of scanning in the direction of the other [a] scanning axis having the higher [, of the first scanning axis and the second scanning axis, having a high] scanning frequency.

5. (Amended) A [The] scanning probe microscope according to [of] claim 3; [,] wherein the scanning control means receives the feedback signal and performs feedback control by controlling the probe position in accordance therewith such [so] that the relative position and displacement of the probe with respect to the sample in the direction of the [a] scanning axis having the lower [having a low] scanning frequency [,] of the first scanning axis and the

second scanning axis, becomes constant during one <u>half</u> period of scanning in the direction of <u>the other</u> [a] scanning axis <u>having the higher</u> [, of the first scanning axis and the second scanning axis, having a high] scanning frequency.

6. (Amended) <u>A</u> [The] scanning probe microscope <u>according to</u> [of] claim 2<u>;</u> [,] wherein the scanning control means performs raster scanning control so that a scanning range <u>of the sample surface</u> in a direction of at least one [scanning axis,] of the first scanning axis and the second scanning axis [of the raster scanning,] <u>is larger than and</u> includes a range <u>of the sample surface</u> being observed [and a larger range].

7. (Amended) <u>A</u> [The] scanning probe microscope <u>according to</u> [of] claim 6<u>;</u> [,] wherein the scanning control means performs raster scanning control <u>such</u> [so] that a scanning range <u>of the sample surface</u> in a direction of <u>the</u> [a] scanning axis having <u>the higher</u> [a high] scanning frequency [,] of the first scanning axis and the second scanning axis [of the raster scanning,] <u>is larger than and</u> includes a range <u>of the sample surface</u> being observed [and a larger range].

8. (Amended) <u>A</u> [The] scanning probe microscope <u>according to</u> [of] claim 7<u>;</u> [,] wherein the displacement <u>detection</u> [detecting] means commences sampling [,] and storage [into a storage device,] of relative position and displacement

values of the probe relative to the sample in a direction of the first scanning axis, the second scanning axis and the third scanning axis at a predetermined [an arbitrary] sampling period, at the [same] time [as] the relative position and displacement of the probe with respect to the sample in a direction of the [a] scanning axis having the higher [a high] scanning frequency [,] of the first scanning axis and the second scanning axis [of the raster scanning,] enter a range being observed.

9. (Amended) A [The] scanning probe microscope according to [of] claim 7; [,] wherein the displacement detection [detecting] means commences sampling [,] and storage [into a storage device,] of relative position or displacement values of the probe relative to the sample in a direction of the first scanning axis, the second scanning axis and the third scanning axis at a predetermined [an arbitrary] sampling period [,] at a point in time when [where] the rate of change over time of the relative position or displacement of the probe with respect to the sample in a direction of the [a] scanning axis having the higher [a] scanning high frequency [,] of the first scanning axis and the second scanning axis [of the raster scanning,] becomes [become] constant or becomes [become] a predetermined value.

10. (Amended) A [The] scanning probe microscope according to [of] claim 7; [,] wherein the displacement detection [detecting] means commences sampling [,] and storage [into a storage device,] of relative position or displacement values of the probe relative to the sample in a direction of the first scanning axis, the second scanning axis and the third scanning axis at a predetermined [an arbitrary] scanning period [,] at a point in time when two conditions occur, the first condition occurring when [, namely] the relative position or displacement of the probe with respect to the sample in a direction of the [a] scanning axis having the higher [a high] scanning frequency [,] of the first scanning axis and the second scanning axis [of the raster scanning,] enters [entering] a range being observed, and the second condition occurring when the rate of change over time of the relative position or displacement of the probe with respect to the sample in a direction of the [a] scanning axis having the higher [a high] scanning frequency [, of the first scanning axis and the scanning axis of the raster scanning, becoming] becomes constant or becomes [becoming] a predetermined value [, are satisfied].

11. (Amended) A [The] scanning probe microscope according to [of] claim 8; [,] wherein the scanning control means receives the feedback signal and performs feedback

control in accordance therewith so that rate of change over time of the relative position and displacement of the probe with respect to the sample in the direction of a scanning axis having the higher [a high] scanning frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [,] become a set value [,] until the relative position and displacement of the probe with respect to the sample in the direction of the scanning axis having the higher [a high] scanning frequency enter a range being observed.

12. (Amended) A [The] scanning probe microscope according to [of] claim 8; [,] wherein the scanning control means receives the feedback signal and controls an amount of displacement of the probe in a direction of the [a] scanning axis having the higher [a high] scanning frequency to be larger than a region to be observed so that rate of change over time of the relative position and displacement of the probe with respect to the sample in the direction of the [a] scanning axis having the higher [a high] scanning frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [,] become constant [,] until the relative position and displacement of the probe with respect to the sample in the direction of the scanning axis having the higher [high] scanning frequency enter a range being observed.

13. (Amended) A [The] scanning probe microscope according to [of] claim 1; [,] wherein the scanning control means comprises [a] scanning speed adjustment means for adjusting the speed of the raster scanning in the direction of one of the first and second scanning axes, and sampling pulse generating means for generating sampling pulses at predetermined times.

14. (Amended) A [The] scanning probe microscope according to [of] claim 13; [,] wherein the scanning speed adjustment means adjusts the relative speed of the probe with respect to the sample in the direction of the [a] scanning axis having the higher [a] high scanning frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [,] so that a control error in the direction of the third scanning axis is minimized.

15. (Amended) A [The] scanning probe microscope according to [of] claim 13; [,] wherein the scanning speed adjustment means keeps constant the relative position or displacement of the probe with respect to the sample in the direction of the [a] scanning axis having the lower [a low] scanning frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [, constant].

16. (Amended) A [The] scanning probe microscope according to [of] claim 13; [,] wherein the scanning speed adjustment means adjusts the relative speed of the probe with respect to the sample in the direction of the [a] scanning axis having the higher [a high] scanning frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [,] so that an absolute value of a control error in the direction of the third scanning axis is minimized.

17. (Amended) A [The] probe scanning microscope according to [of] claim 16; [,] wherein the sampling pulse generating means generates a sampling pulse every time the relative position or displacement of the probe with respect to the sample in the direction of the [a] scanning axis having the higher [a high] frequency [,] of the first scanning axis and the second scanning axis of the raster scanning [,] become a predetermined value.